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HIGH ALTITUDE OBSERVATORY

of

Harvard University and University of Colorado

TECHNICAL REPORT

The High Altitude Observatory Isophotal Contour Densitometer

by

Fred E. Fowler

Donald S. Johnson

Donald _ Billings

29 January 1952

ONR Contract N8onr 64801

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I. INTRODUCTION

For many years the High Altitude Observatory has engaged in a program of observations of the spectacular motions of giant solar prominences rendered visible in monochromatic light by the Climax coronagraph. Motion picture studies of these films and similar ones taken at other observatories have revealed the extraordinary nature of the force fields involved, and have pointed to the need for further quantitative work, particularly that involving the measurement of the growth of luminous areas in prominences as a function of time.

An attempt was made to analyze the prominences by a photographic determination of isophotal contours, using the method suggested by Brian O'Brien [1] of developing the film to extremely high contrast. It was found that the isophotal contours were very helpful in interpreting solar phenomena but that the process was time-consuming. Two other methods of plotting isophotal contours which have been used in the study of galaxies were also deemed to be impractical for our purpose. The Williams-Hiltner microdensitometer [2, 3, 4], can be operated to plot very satisfactory isophotal contours, but it has three serious limitations in prominence work: (1) Its use is too time-consuming for the study of the many frames in the film of a rapidly changing prominence; (2) it requires an enlargement of a photograph to proper dimensions for effective use, which in turn introduces difficulties in the standardization of the photometry as well as additional work; and (3) it does not give automatically a numerical value for the area enclosed within a contour. The plotting of isophotal contours from a series of microdensitometer tracings, as used by Miss Patterson [5] and D. S. Evans [6] appears to be an even more time-consuming procedure, and would lead to less satisfactory results in our problem.

Because of the limitations for this work of other contouring methods the staff of the High Altitude Observatory has sought to develop a new type photometer capable of analyzing films from motion picture sequences fast enough for the problem at hand. The isophotal contour densitometer described in this report is a first breadboard model of an instrument of this type. It has the requisite speed, being capable of plotting a contour in approximately seven seconds; it possesses much flexibility as to the type of photographic plate which it will analyze, using directly the 35 mm negatives from

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1) O'Brien, Brian, Ap. J., 89, 1939.

2) Publications of the Observatory of the University of Michigan, 8, 45 (1940).

3) Ibid., page 103.

4) Williams, R. C., and Hiltner, W. A., Ap. J., 98, 43, 1942.

5) Shapley, H., "Galaxies" page 170, Blakeston Company, Philadelphia, 1943.

6) Evans, D. S., M. N., 109, 94, 1949.

coronagraphs and flare cameras; and it can be set up readily to measure and record automatically the area within a given contour.*

We deem its realm of potential application far wider than the measurement of the changes in the luminous areas of solar prominences, and outline a few suggestive further uses in this report.

II. USES OF THE HIGH ALTITUDE OBSERVATORY CONTOUR DENSITOMETER.

A. General Purpose.

The High Altitude Observatory contour densitometer is an electronic device for indicating which areas on a photographic plate have densities greater than any specified amount. By the addition of a simple integrating circuit such a mechanism becomes also a device for determining numerically the extent of these areas. Because it can be made to draw accurate contours much more quickly than can be done with contouring methods now in use such an instrument has a number of applications in solar research. At present a working pilot model of the instrument has been put into operation at Boulder, Colorado at the laboratories of the Observatory.

B. Uses in Solar Research.

The contour densitometer has potential applications at the High Altitude Observatory in the study of solar flares, solar prominences and coronal emission lines. We expect that the detailed knowledge of the structure of solar flares to be gained from sets of isophotal contours will give much insight into their nature and origin. Also for the statistical correlation of flare activity with other solar and terrestrial phenomena we would like to be able to quickly obtain numerical values of flare areas. If we turn it to a solar prominence the contour densitometer should give immediate information about the distribution of luminous material and the position and shape of the most brilliant portion of the prominence. In fact it was for this application that we began our work on the contour densitometer.

When applied to coronal spectral lines it should solve many of the difficulties involved in the routine coronal photometry of the High Altitude Observatory. In this photometry we are especially concerned with the correlation of the location of bright portions of certain coronal emission lines with solar and ionospheric events. Since a routine tracing of line profiles at specified intervals around the solar disk would be exceptionally laborious, a procedure has been worked out for routine work in which the coronal lines are compared

*Note added after completion of Report: We have recently learned of an automatic density analyzer developed by Hogen Laboratories, Inc. that works from a photographic print and has several features which appear to be common to ours.

visually with a set of standard lines, the latter in turn being compared with the set of photometric spots impressed on each plate. By means of an attachment which has now been constructed for our present contour densitometer, however, it is now possible either to read directly the illumination for any point in any spectral line, in terms of the illumination of the photometric spots, as well as to locate immediately the points of maximum density. Our experiments indicate that we may be able later to replace the more subjective visual photometry with a sound quantitative scheme based on the new contour densitometer.

C. Possible Applications Outside the Field of Solar Research.

A number of possible applications of a contour densitometer of this sort outside the field of solar research have come to our minds. As it stands, the device should be useful in the study of the shape of nebulae and galaxies, and we think that with certain modifications it could be used in the counting and classification of stars. An obvious terrestrial application is the rapid study of motion picture photographs of combustion processes and similar phenomena such as exhaust gas distributions in jet engines. Other possible applications are in the field of aerial photography. For example, if it is desired to rapidly identify the details in two photographs, portions of which cover the same region, the densitometer can be set to select for comparison only certain of the more dense details. As another example, the areas of geographical features which photograph with distinguishing densities in aerial photography (such as forests, lakes, snow fields, etc.) could be determined by it in a matter of seconds. Thus one might conduct rapid surveys, from photographs, of forest areas, etc. With the addition of recording apparatus, the instrument, we believe, could be built so that by a single switching operation it can be converted into a two-dimensional microdensitometer, giving simultaneously tracings of density versus distance along as many lines of any shape in a photographic plate as one might care to record.

III. A GENERAL DESCRIPTION OF THE PILOT INSTRUMENT NOW COMPLETED.

The pilot instrument which has been completed and is in operation at the High Altitude Observatory Laboratory is based in part on a system suggested by Babcock[7] and includes added features suggested by John W. Evans of our staff. In its operation, a beam of electrons, by both horizontal and vertical displacement, strikes in succession all points in a rectangular portion of the screen of a cathode ray tube. The resulting moving spot of light is focused

7) Babcock, H. W., "A Con tour Photometer," Publications of the Astronomical Society of the Pacific, 62, 18-21, 1950.

on the film to be analyzed. The intensity of the light transmitted through the film, by its action on a photomultiplier tube, determines whether or not the beam of a second cathode ray tube (the horizontal and vertical motion of which is synchronized with the first) is blocked. As a consequence there is traced on the screen of the second tube a pattern of that portion of the scanned area of the film above a certain density.

This pilot instrument differs from that suggested by Babcock primarily in that by the use of high-resolution magnetic type cathode ray tubes it is possible to obtain a complete contour of a film from a single scanning. Another and more radical difference is contemplated in the finished instrument yet to be built. This is the introduction of a second photomultiplier tube and optical system to scan a standard film or wedge of known density. As it will balance the signals from the two photomultiplier tubes, the densitometer will be a truly null-instrument, showing on the observing screen a pattern of the areas on the film of density greater than that on the standard film, with errors from various sources balanced out. A block diagram showing the general features of the contemplated instrument is given in Figure 8. Those features not in the present model are identified.

The essential parts of the present model are: (Refer to Figure 8)

A. A pair of sweep circuits which causes a beam of electrons to trace out a rectangular pattern on the screen of a cathode ray tube that we call the "scanning tube." The vertical sweep takes place in 1/60 second, the horizontal in seven seconds.

B. An optical system consisting of two lenses, the first of which images the moving spot of light of the scanning tube screen upon the photographic film to be analyzed. The second lens images the aperture of the first upon the cathode of a photomultiplier tube. The first lens is diaphrammed so as to have an aperture the image of which just fills the cathode of the photomultiplier tube.

C. A circuit for applying D. C. amplification to the signal from the photomultiplier tube and comparing the amplified signal with an adjustable comparison voltage. The signal from the photomultiplier tube is fed into the amplifier circuit in such a way that an increase in photomultiplier plate current causes a decrease in the output of the amplifier. The amplified signal and the variable D.C. comparison voltage are applied to the cathode and anode of a mixing diode. When the density of the film being analyzed is such that the cathode of the diode is less positive than the anode, the tube conducts. One part of a flip-flop circuit coupled to the diode conducts when the diode is conducting, the other when it is not.

D. A viewing tube. A second cathode ray tube is used for viewing the areas of the film whose densities are above the amount determined by the setting of the comparison voltage. The horizontal and vertical deflection coils of this tube are connected in parallel with those of the scanning tube, so that the horizontal and vertical sweeps of the two tubes are always synchronized. The bias of the viewing tube is controlled by the flip-flop circuit, the tube being blanked whenever the mixing diode is not conducting. There appears, therefore, on the viewing tube a bright pattern of all areas on the scanned portion of the photographic plate of density greater than a determined amount. Two phosphors on the viewing screen, a short-lived blue and long-lived yellow, make the pattern suitable either for photographic or visual study.

E. An attachment for use of the instrument in the photometry of coronal plates. This consists of a plate holder which permits easy horizontal and vertical positioning of the plate, and of an optical system which diverts a portion of the raster image around the plate and through a high-gradient wedge. Figure 18.) When this attachment is in place, one sees on the left side of the viewing screen a pattern of that part of the spectral line above a given density, and on the right side a rectangular area part of which is dark. (Figure 19) To operate, first the standardizing spots on the plate are successively positioned for scanning, and the comparison voltage is adjusted so that the images of the spots on the viewing screen are just blocked. The corresponding positions of the edge of the dark area on the right side of the screen are marked on a scale fastened to the front of the viewing screen. The coronal plate is then positioned so that a portion of a coronal line is being scanned. The comparison voltage is set to give a desired image of the line on the viewing screen (i.e., an image with only the points of maximum density unblanked, or with the edge of the unblanked region at a point of interest on the solar circumference.) The illumination corresponding to blanking in terms of the photometric spots, is read directly from the position of the boundary between the blanked and the unblanked regions on the right hand side of the viewing screen.

IV. OPERATING CHARACTERISTICS OF THE PILOT INSTRUMENT NOW CONSTRUCTED.

We have now tested the operation of the pilot instrument extensively and have determined its general properties in preparation for the construction of a final model.

A. Our objectives in the testing we have now done were:

1. To test the usefulness of the instrument as it now stands.

2. To obtain data for predicting the operating characteristics of an instrument in which the comparison voltage is replaced by a circuit containing a photomultiplier tube illuminated by the scanning tube, but viewed through a standard density.

3. To obtain data for predicting the operating characteristics of a final model of the instrument with a comparison photomultiplier tube as described above, and in addition using an A.C. rather than the present D.C. amplifier.

B. Operating Characteristics of the Scanning System as Determined by Tests.

The sweep circuits produce on the scanning screen a raster which can be varied conveniently from approximately 2.5 x 5 cm. to 4 x 8 cm. Photoelectric measurements indicate that no inequalities in the brightness of the raster are readily attributable to nonlinear sweeping. Since the brightness is easily adjusted over a wide range of values, it proves to be variable most satisfactory for accommodating various density ranges. A high resolution optical system sweeps an area on the film 1/10 the dimensions of the raster; a low resolution system, an area 3/10 the dimensions of the raster.

C. Operating Characteristics of the Detector as Determined by Tests.

We analyzed the cathode voltage of the pentode which serves as the cathode-follower of the photomultiplier tube by inserting into the optical system a series of densities ranging from 0.00 to 3.34. From the pattern on an oscilloscope screen of the voltages we obtained a fairly accurate measurement of the signal (average level during scanning minus average level during blanking), and estimated the peak-to-peak noise. In Figure 1 the logarithm of the signal and the logarithm of one-half the peak-to-peak noise are plotted against density. The noise found here is the high-frequency photo-tube noise. For very low densities a noise of much lower frequency becomes apparent which completely masks the tube noise. This low frequency noise comes, we believe, from the irregularities in the phosphor of the scanning tube and we expect that it will be compensated out by the use of the comparison photomultiplier tube we expect to use in the final model.

D. Operating Characteristics of the Amplifier and Viewer System as Determined by Tests.

We conducted measurements with known densities to determine the density-discrimination of the densitometer in its present

form and the density-discrimination which may be expected if the comparison voltage potentiometer is replaced by a comparison photomultiplier tube system. For each of three ranges of densities the brightness of the scanning tube and the operating levels of the D.C. amplifier were adjusted so that the corresponding comparison potentiometer settings covered most of the range of the potentiometer. For each density, four potentiometer settings were determined.

(a). The setting which completely blanked the whole viewing screen.

(b). The setting which completely unblanked the whole viewing screen.

(c). The setting which caused a predetermined point on the viewing screen to be blanked for successive sweeps.

(d). The setting which caused the same point to be unblanked for successive sweeps.

These settings, for the three ranges of densities, are plotted against density in Figure 2. Data (c) and (d) were not obtained for the lowest density.

In each case the horizontal displacement between curves (a) and (b) represents the density-discrimination of the apparatus as in use, whereas the discrimination which should be obtainable with a comparison photomultiplier tube circuit is represented by the horizontal displacement between curves (c) and (d). The light and voltage levels were set up to give convenient potentiometer readings. Subsequent experience has shown that these are not the levels for maximum density-discrimination. Note, for example, the density discrimination possible with an optimum choice of operating levels as shown in Figure 5.

E. Performance Tests on Prominence, Flare, and Coronal Spectra Photographs.

1. Four solar prominences were analyzed, and photographs taken of the viewing screen when the potentiometer was set for various densities. Sets of isophotal contours traced from three of these are given in Figures 3, 4, and 5. An enlargement of the negative of a fourth prominence viewed and enlargements of negatives of the photographs of the viewing screen for different density settings are also included. (Figure 7.)

2. We then demonstrated to our satisfaction that the densitometer is useful for a study of solar flares and of coronal spectra. Figure 6 gives a set of isophotal contours in a solar region containing a flare and sunspots. By setting the densitometer to unblank the viewing tube for densities below the level of the solar disk and tracing the outline of the portion of the screen which remained blanked we obtained contours within the sunspot. Setting it for higher densities gave us contours in the flare areas.

Emission and absorption lines in the coronal spectrum appear as bright and blanked lines, respectively, on the viewing tube. A density gradient along the spectral line can be immediately detected by setting the comparison voltage so that only the portions of the line above a certain density appear on the screen. By means of the attachments described in part III-E we can study coronal lines, and preparations are being made to put the instrument into test use for the routine analysis of these lines. See Figure 20.

V. PROPOSED MODIFICATIONS IN A FINISHED INSTRUMENT.

A. Use a Different Set of Deflection Coils.

The deflection coils now in use were not designed for the particular cathode ray tubes being used, and although they work fairly well, a better raster can certainly be obtained with the proper coils. It is recommended that the new set of coils be of the push-pull type. Under the present set-up the varying load during a sweep required an unnecessarily elaborate set of voltage regulated power supplies.

B. Modify the Optical System to Increase the Light on the Photocathode.

Since in the present set-up, the signal-noise ratio is 1:1 at density of 2.8, the use of the densitometer for higher densities will require a more efficient optical system. It will be easy to make significant improvements here.

C. Introduce a Comparison Photomultiplier Tube Circuit Which Will Receive Light from the Scanning Tube through a Wedge of Known Density.

This feature has been contemplated throughout in the design of the instrument. It was not included in the pilot instrument because we believed that the operating characteristic data could be obtained more readily without it. Its desirability

has been thoroughly proved from the observations on the pilot densitometer. It will automatically compensate for the following:

1. Irregularities in the phosphor of the scanning tube.

2. Variations in the brightness of the scanning beam due to power line fluctuations.

3. Variations in the distribution of light over the scanning screen due to changes in the intensity of the electron beam. It will also provide a convenient means of assigning an absolute value to the density of a given contour.

D. Use an A.C. Rather than a D.C. Amplifying System.

The present D.C. system, besides being subject to drifts, requires a revision of levels throughout whenever densities are changed radically. An A.C. system is contemplated which should be stable and not require adjustment over a wide range of densities.

E. Introduce an Integrating Device.

This is another feature which has been contemplated throughout the design of the instrument. Either a circuit which charges a condenser whenever the viewing tube is unblanked or a counter which is operating when the tube is unblanked will give, at the end of each seven-second sweep, an expression for the area greater than a given density on the swept portion of the film.

F. Design and Construct an Appropriate Housing.

Provision should be made in such a housing for mounting a 35 mm film and for changing it quickly from frame to frame. There should be a two-dimensional adjustment for positioning the film so that the desired portion of a frame may be studied as a motion picture. The optical system should be mounted so as to permit convenient initial adjustment, then can be locked into place. The same is true of the electrical circuit which, for routine work, should be operated by as simple a set of controls as is possible.

VI. APPENDIX

A. A More Detailed Description of Electronic Circuits.

The general layout of the High Altitude Observatory Contour

Densitometer as contemplated in its final form is represented diagramatically in Figure 8. If the reference photomultiplier and the integrator are omitted from the diagram, the instrument in its present form is represented.

The horizontal and vertical deflection coils of the magnetic deflection type cathode ray tubes (5 FP 7) are driven by one set of horizontal and vertical sweep circuits; the Z-axis (beam intensity) of the scanner tube is modulated manually, that of the viewer tube modulated by the signal from the photomultiplier tube so as to be either blanked or unblanked, depending on whether or not the density of the photographic plate being scanned is below or above a critical amount.

The sweep frequencies generating the raster on the scopes are kept relatively low to simplify the sweep-driver circuits and to minimize the bandwidth requirements of the comparison circuits and Z-axis modulator. The resolution desired is in the order of 400 lines so the circuits in question must respond adequately to a pulse of width $1/400 \times 1/f_h$ seconds where f_h is the frequency of the fast sweep. For convenience, 60 c/s is chosen for one of the sweep frequencies enabling the sweep generation to be timed by the power line. To keep frequencies down, this is chosen as the fast sweep. An orthogonal sweep of frequency $f_2 = 1/7$ c/s then creates a raster resolved into $7 \times 60 = 420$ lines. Thus the Z-axis modulation circuits must transmit without modulus or phase distortion flat topped pulses of width $\delta T = 1/400 \times 1/60$ sec $= 42$ microseconds.

It has been remarked that the fast sweep is timed by the 60 c/s power line. The two sweeps are locked together by coupling the slow sweep also to the power line. This is accomplished by using a power line driven synchronous motor and cam-operated switch to time the slow sweep.

B. The separate portions of the system outlined above are now to be described.

1. Vertical Sweep Circuits.

The block diagram of the vertical sweep circuits is given in Figure 9. (Refer also to the complete sweep-circuit diagram). This is a fairly straightforward circuit using the power line voltage wave to time the discharge of a capacitor being charged in a pentode charging circuit. A push-pull power amplifier drives the deflection coils. The individual elements of Figure 9 are described below. The voltage wave-forms at various points are shown in Figure 10.

a. Square Wave Generator.

The voltage from the 60 c/s power line is here transformer-coupled to a 6AL5 diode rectifier and 6AU6 zero biased pentode amplifier to generate a square wave.

b. Pulse Generator.

Here the square wave is differentiated by an R-C network. A 6AL5 diode removes all negative pulses. The result is a train of positive pulses appearing at a rate of 60 c/s.

c. Sweep Generator.

The sweep is generated by a capacitor charging through a 6AU6 pentode functioning as a constant-current source. The high cathode resistance of the 6AU6 is unbypassed to insure high linearity. The sweep-generating capacitor is paralleled by a variable resistor to produce a trapezoidal waveform with variable "step." The 12AU7 discharge tube is connected across the sweep-generating capacitor. This tube, normally cut off, is caused to conduct in a region of low plate resistance by the pulses from the pulse generator, discharging the capacitor and thus causing the sweep to be generated at the same repetition rate as that of the pulses.

d. Amplifier.

Here the sweep voltage waveform is balanced to ground and applied to a 6L6 push-pull cathode-loaded power output stage designed to develop a sawtooth current wave in the horizontal deflection coils. Two feedback loops, one positive and one negative, are employed to control the linearity of the sweep as generated by the current in the low resistance deflection coils.

e. Sweep Return Blanking Circuit.

The pulses which are injected into the discharge tube are also sent to a blanking circuit which cuts off the cathode ray tubes during the discharge and thus prevents the return trace from appearing on the screen.

2. Horizontal Sweep Circuits.

The block diagram of the horizontal (slow) sweep circuits is given in Figure 11. Here again the sweep voltage is generated by a capacitor charging through

a pentode. A single-ended cathode-loaded output stage drives the horizontal deflection coils. D. C. coupling is necessitated by the slow rate of sweep. The individual blocks are discussed below.

a. Sweep Generator.

A capacitor charging through a 6AU6 pentode with unbypassed cathode resistor is again used to generate the sweep voltage. Due to the low sweep frequency, it was found propitious to use a synchronous motor and cam periodically closing a switch to discharge the sweep-generating capacitor. The synchronous motor is driven from the 60 c/s power line. Since the vertical sweep is also driven from the power line, the two sweeps are locked in.

b. Sweep Amplifier.

At present the output of the sweep generator is cathode-coupled into a single-ended cathode loaded output stage consisting of three type 6L6 beam tetrodes operating in parallel. The screens of the 6L6's are properly biased and kept in motion parallel to the cathodes by driving them from a cathode loaded 5687 which received the same grid signal waveform as the 6L6 tubes.

c. Sweep Return Blanking.

A contact on the discharge switch applies the appropriate voltage to the blanking tube to cut off the C.R. tube during the discharge and so prevent the return trace from appearing on the screen.

3. Comparison Circuits.

The present comparison circuit is delineated in Figures 12 and 13. The photomultiplier tube drives directly the grids of a 6J7 cathode follower After D.C. amplification the signal is fed to an amplitude selector which passes a signal only when the reference voltage is surpassed by that resulting from the density of the image being studied. This output signal triggers a bi-stable flip-flop circuit which puts a positive, flat-topped square wave on the viewing scope grid during selection and leaves this tube cut-off during anti-selection. The resultant image built up on the viewing scope has an area proportional to that portion of the photographic plate which is more dense than the boundary density. The

blocks are described below.

a. Photocell Circuits.

A standard type 931A or 1P21 photomultiplier tube is employed. This is direct coupled into cathode follower stage which transmits the signal at a low impedance level to the amplifier circuit several feet away.

b. Amplifier.

The output of the cathode follower is direct-coupled into a 6AU6 pentode amplifier stage. The output impedance of 6J6 cathode follower is used to by-pass the cathode resistor of the 6AU6 tube.

c. Amplitude Selector.

A fundamental diode selector circuit utilizing a 6AL5 compares the signal with a comparison voltage. The output is constant during anti-selection and is a function of image density during selection.

d. Bi-stable Flip-Flop Circuit.

The amplitude selector is direct-coupled to the input grid of a 12 AU7 connected in a bi-stable trigger circuit configuration. This circuit remains in one of its stable positions most of the time. The grid of the viewer scope is connected to the flip-flop circuit and voltages are adjusted so that the scope is cut off while the circuit is in this stable position. The flip-flop switches to its other stable position only during selection and in this state the output to the C.R. grid is at a higher level which is just right to unblank the tube. Provision is to be made for switching the output of the flip-flop into a differentiating and rectifying network before applying to the C.R. tube grid. The output pulses will then produce a contour line at the boundary density in place of recreating the entire area above this density.

C. Block diagrams of the various voltage supplies for the system are given in Figures 14, 15, 16, and 17.

FIGURE 1. Signal and Noise from the Cathode Follower of the Photomultiplier Tube in the Contour Densitometer

14 December 1951

(Output Voltages in Units of .005 Volts.)

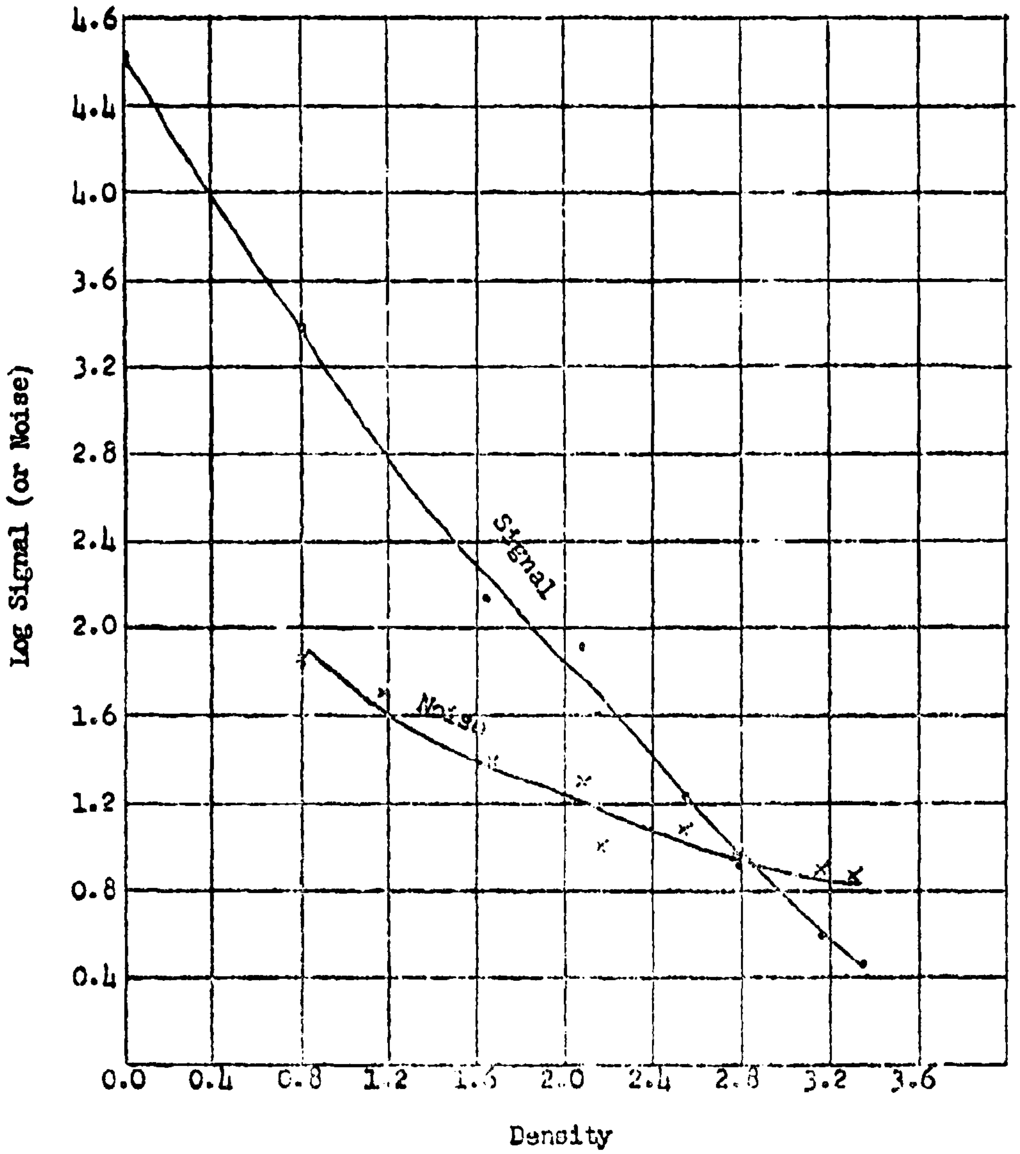


FIGURE 2. Operational Test on Contour Densitometer.

Upper Curve — Screen Completely Illuminated.
Lower Curve — Screen Completely Blank

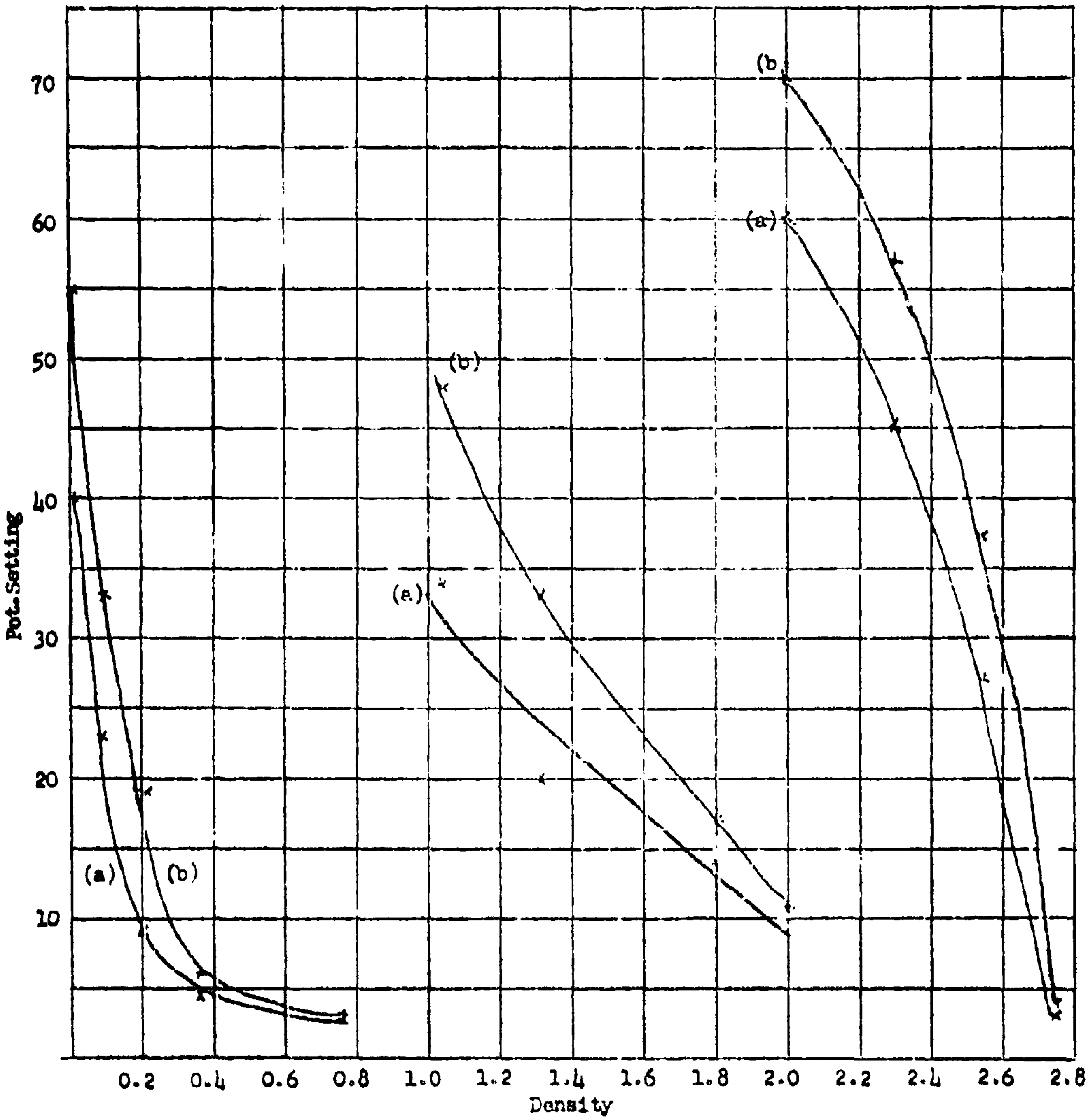


FIGURE 3. Isophotal Contours of an Area Including a Small Solar Prominence.

The prominence photograph when viewed by the eye most closely resembles the region enclosed within the third contour (counting inward). Two significant elements of contour densitometry in prominence study are represented by this set of contours: (1) There is a comparatively high density region not generally observed by the eye, which is sensitive to contrasts surrounding the detailed part of a prominence which the eye does observe. (2) The density gradient of the background near the rim of the occulting disk makes the shape of the contours different from that of the prominence filaments. Consideration is being given to introducing a comparison density with a gradient corresponding to that of the background for the study of prominences with finished instrument.

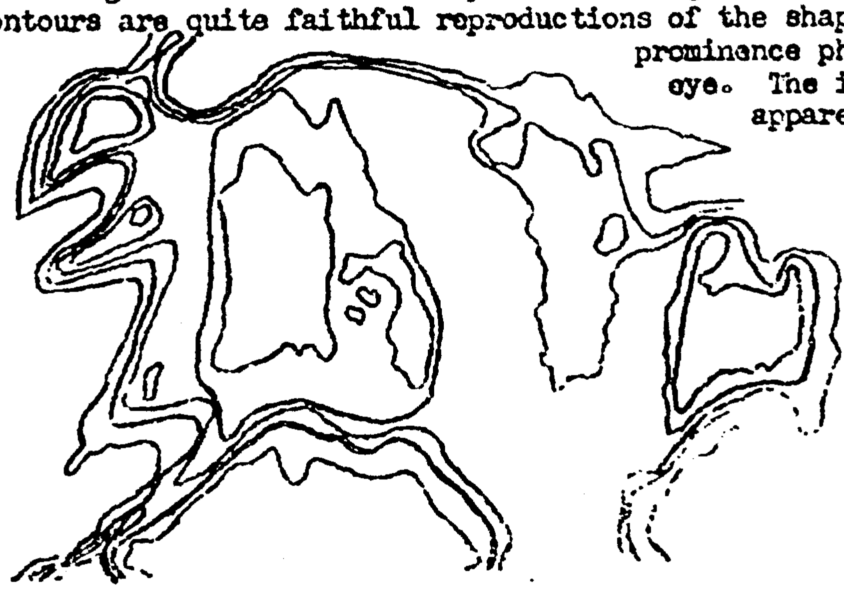
FIGURE 4. Isophotal Contours of a Fountain-Shaped Prominence.

The prominence appears to be erupting from the sun near the center of the contour region, sending one heavy streamer of material to the left and several smaller ones to the right. The first two contours enclose all the streamers and the background to the right-hand streamers. The third

contour encloses only the central core and fragments of the right-hand streamers. The fourth and fifth contours show only the most luminous portion of the central core.

FIGURE 5. Isophotal Contours of a Fragment of Prominence Material.

This fragment was sufficiently distant from the rim of the occulting disk that there was little gradient in the density of the background. Consequently the outermost contours are quite faithful reproductions of the shape of the fragment on the prominence photograph as seen by the eye. The inner detail is not apparent to the eye.



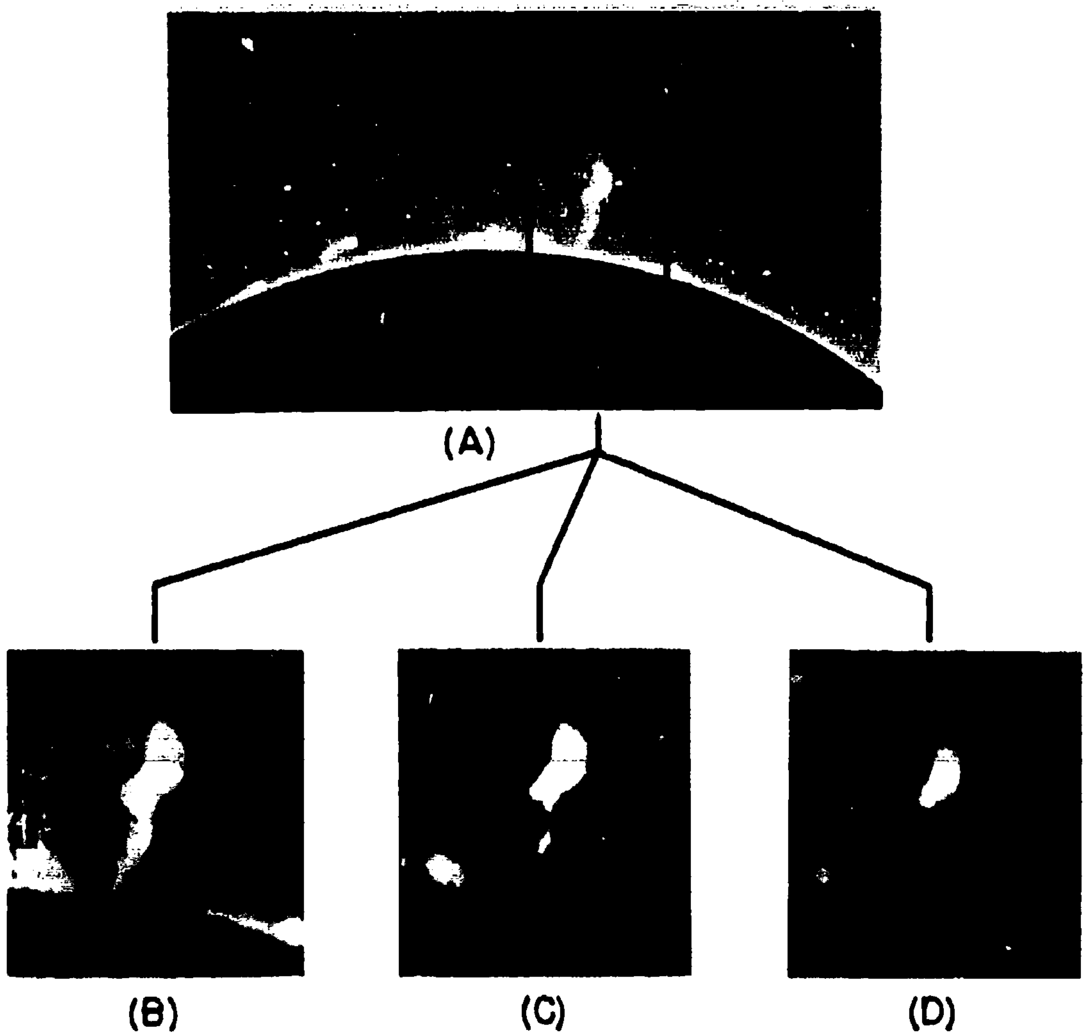
Densitometer measurements show variations in density over the fragment image of the order of 0.06. In the contour densitometer these details move when the film is moved, retaining their general shape. Hence they represent true density contours, and the instrument is capable of density discrimination of the order of 0.01.

FIGURE 6. Isophotal Contours of a Solar Flare.

(The shaded area is a sunspot, the contoure within it giving density levels below that of the solar disk.)

FIGURE 7

A Solar Prominence, Printed Directly from a Coronagraph Negative (A); and Regions in the Same Prominence Bounded by Different Isophotal Contours, as seen on the Viewing Tube Screen of the Contour Densitometer (B), (C), (D).



The rectangle marked on (A) shows the area on the prominence film which was scanned. The photographs (B), (C), and (D) show the viewing screen corresponding to three different density levels, the bright portions of each photograph representing the areas on the prominence film having densities above the reference density for which the densitometer was set. (The irregular bright spots in (B) appear because the densitometer setting was just above the level of the background density. Consequently tube noise, film irregularities, and small irregularities in the scanning tube brightness show as spots on the background.)

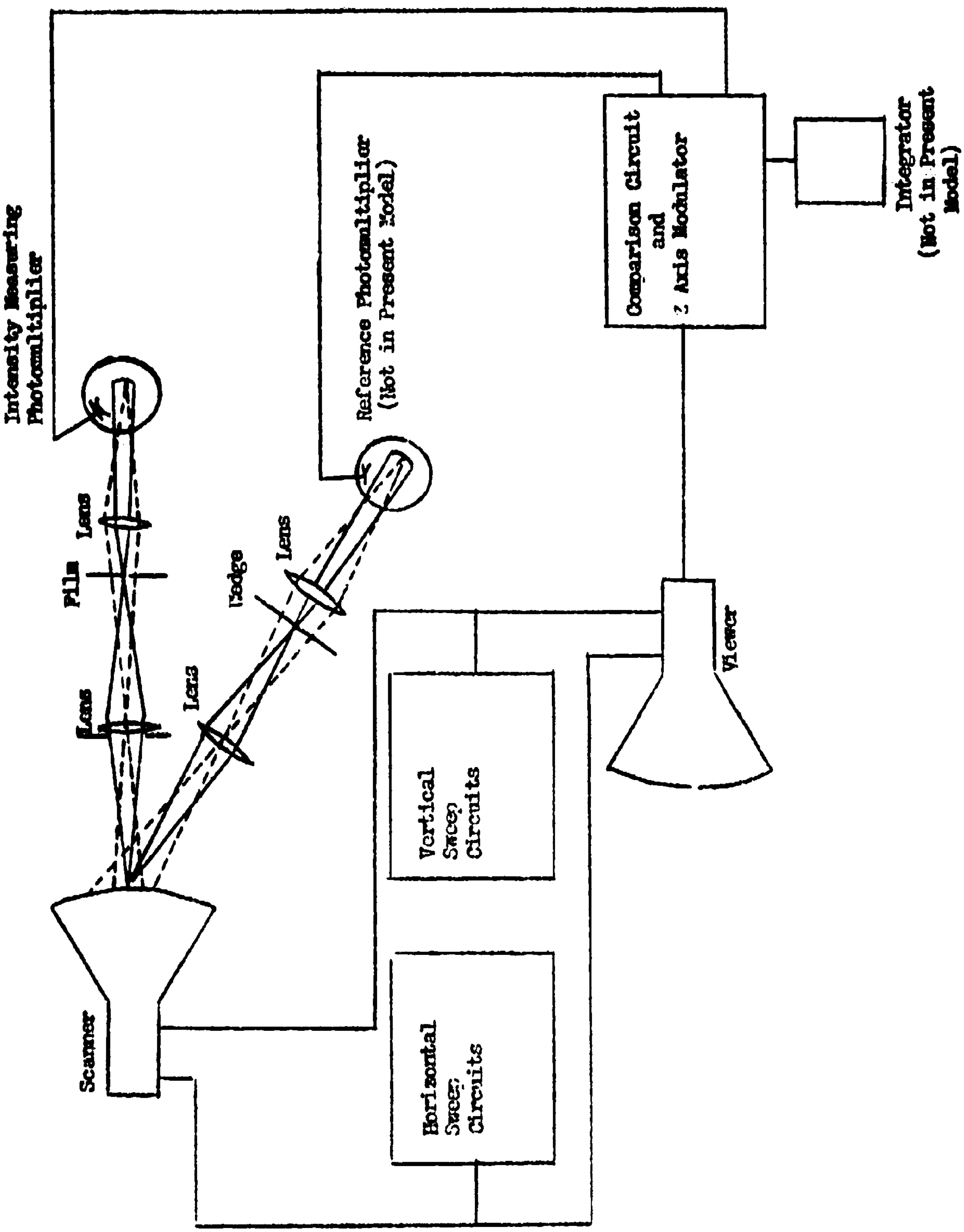


FIGURE 8
Block Diagram of the Contour Densitometer

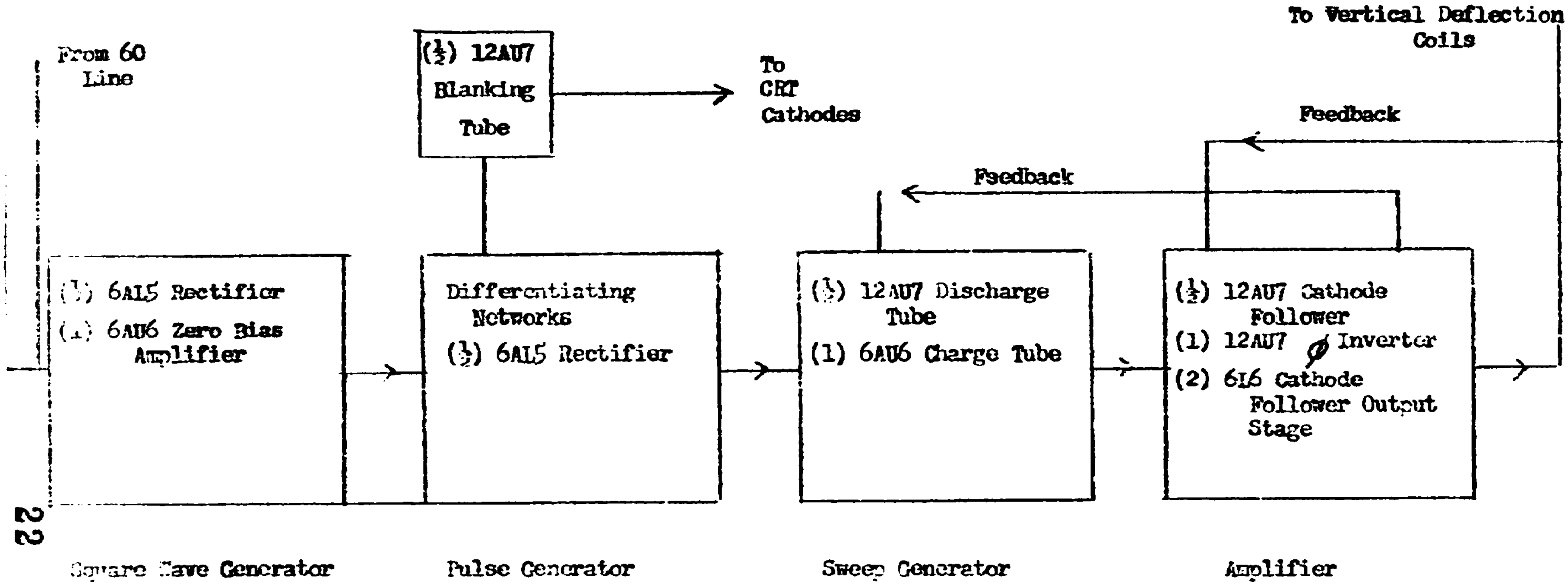


FIGURE 9

Vertical Sweep Circuits

60 cycle bias input

to square wave generator.

Voltage at grid of 6AU6

zero bias amplifier.

Voltage at plate of 6AU6

-- output of square wave

generator.

Differentiated output of

square wave generator.

Output of 6AL6 rectifier

-- signal at grid of 12AU7

discharge tube

Output from sweep

generator.

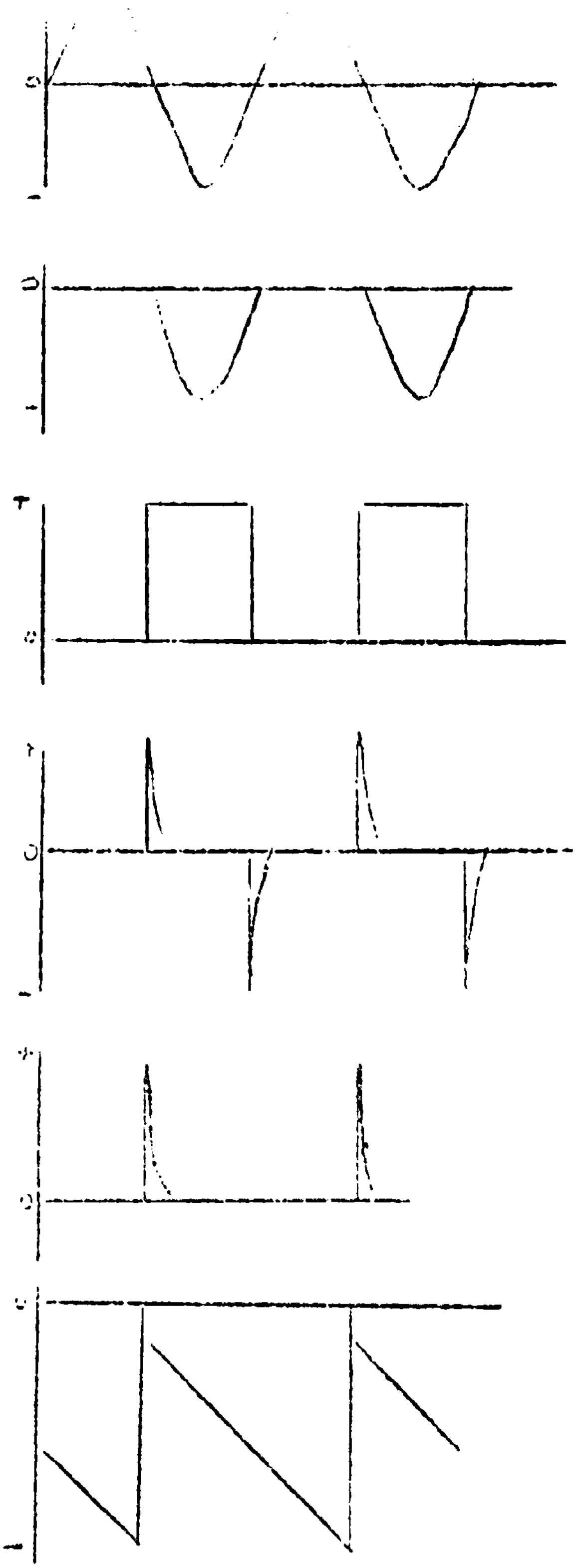


FIGURE 10

The step-plus-sawtooth output of the sweep generator is modified by a feedback loop and applied push-pull to the grids of the deflection coil drivers.

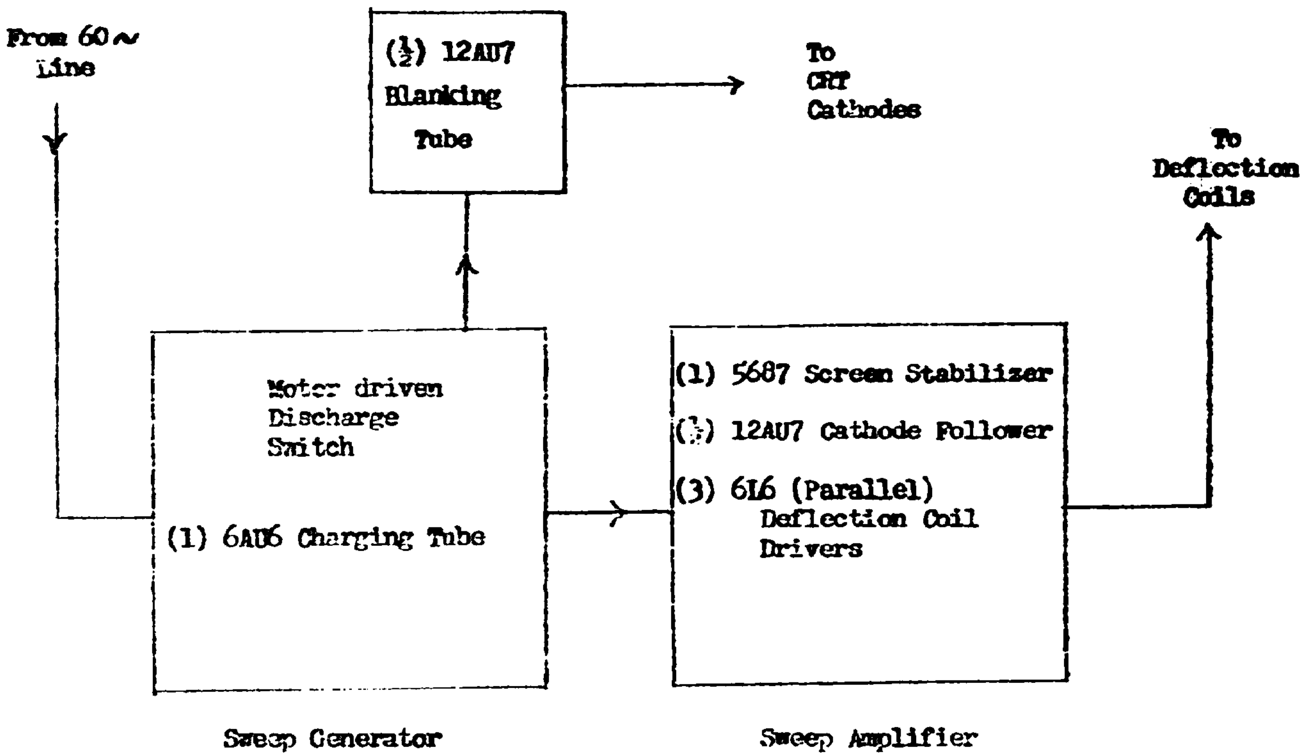


FIGURE 11

Horizontal Sweep Circuits

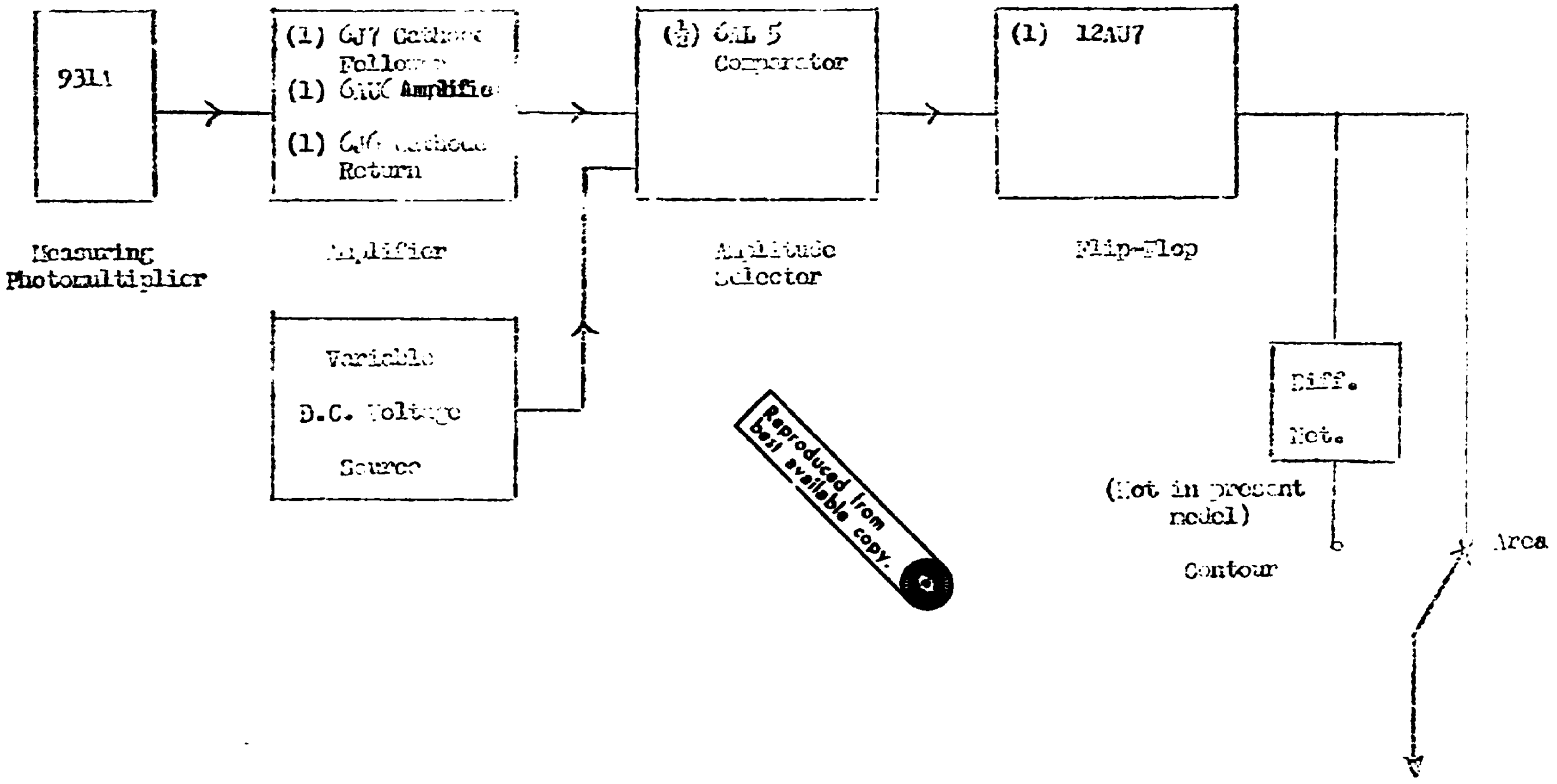


FIGURE 12

Comparison Circuit and Z Axis Modulator

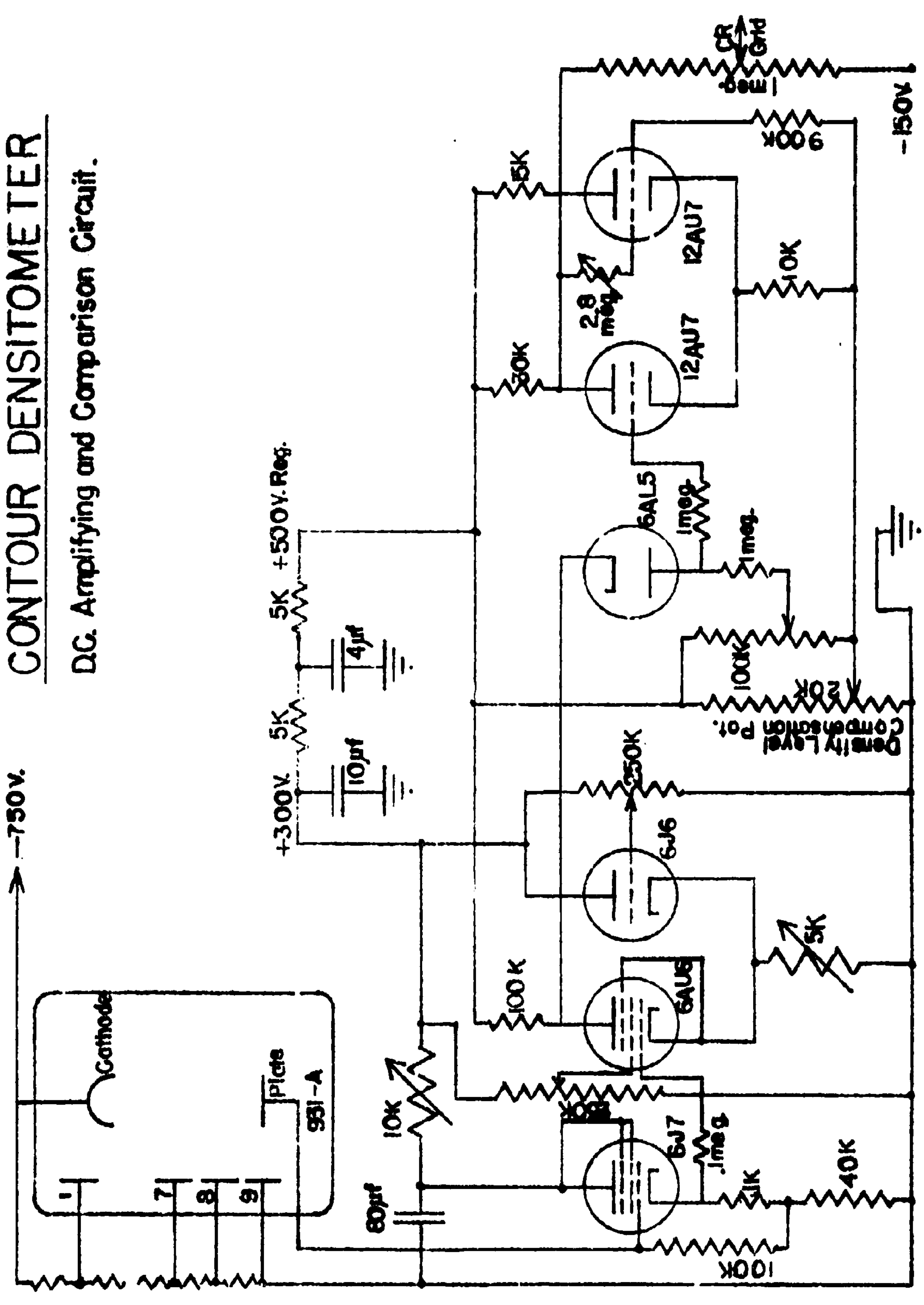

CONTOUR DENSITOMETER
D.C. Amplifying and Comparison Circuit.
-750V.
Cathode
Plate
931-A
1
7
8
9
80pf
10K
100K
6J7
1meg.
1K
40K
100K
6AU6
5K
6J6
250K
+300V.
5K
10pf
5K
4pf
+500V. Reg.
6AL5
1meg.
1meg.
100K
20K
Density Level Compensation Pot.
30K
12AU7
2.8 meg
12AU7
15K
10K
900K
1 meg.
CR
Grid
-150V.

FIGURE 13

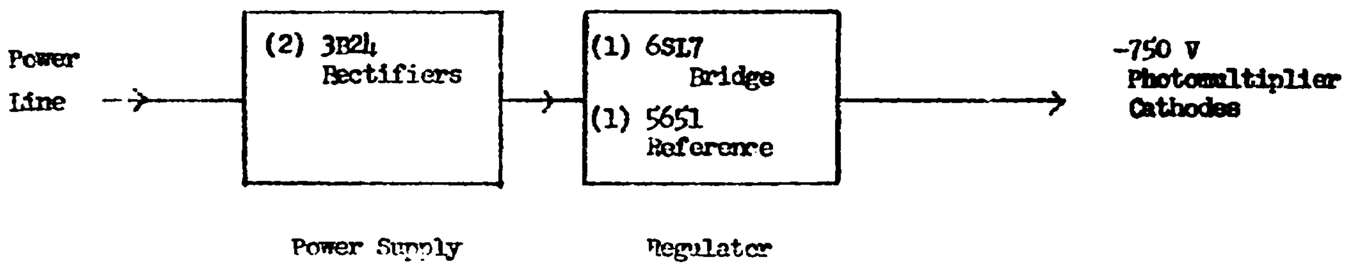


FIGURE 14

"B" Supply # 1

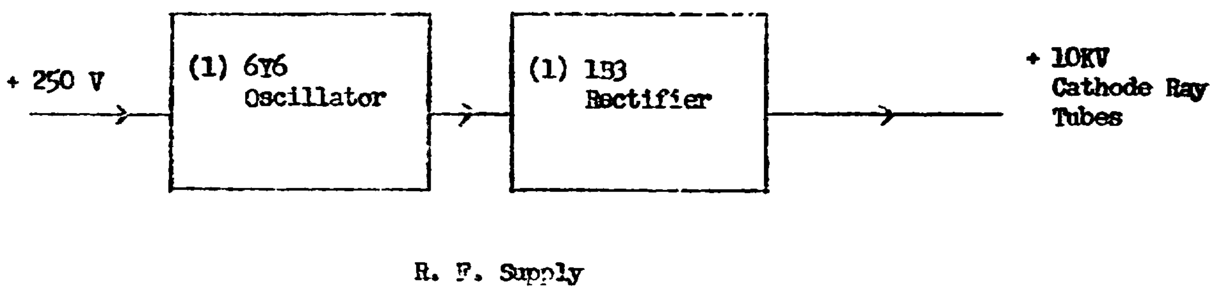


FIGURE 15

"B" Supply # 2

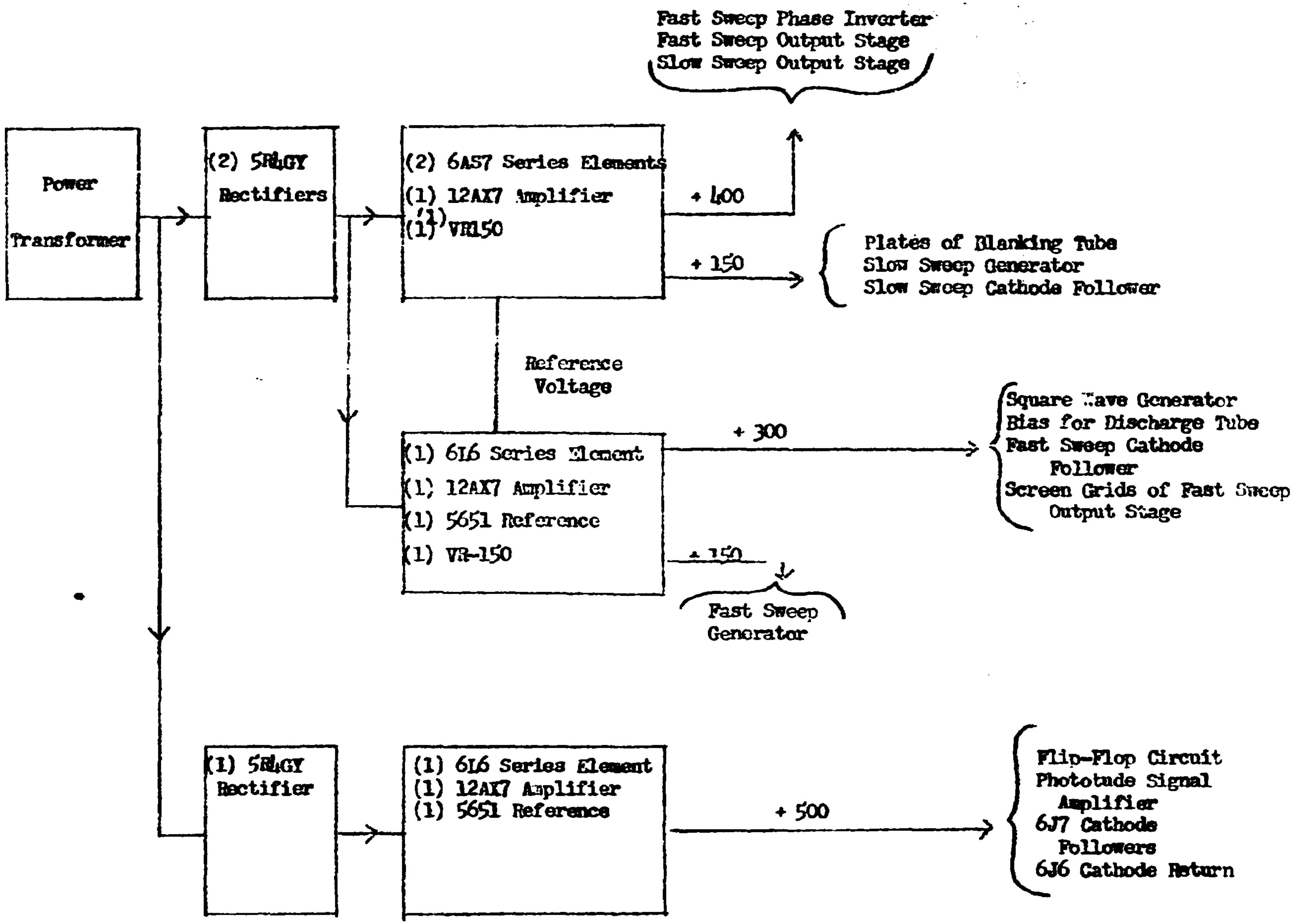


FIGURE 16

"B" Supply # 3

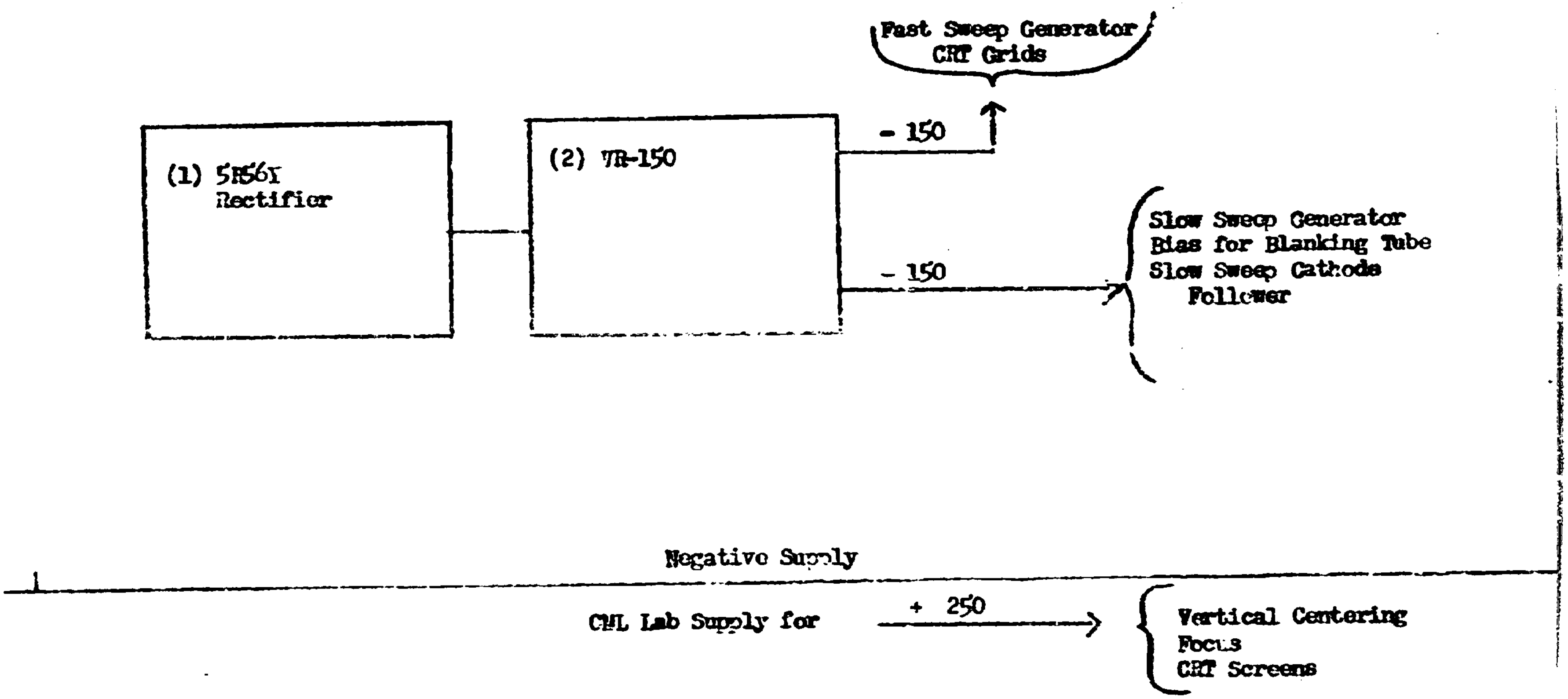
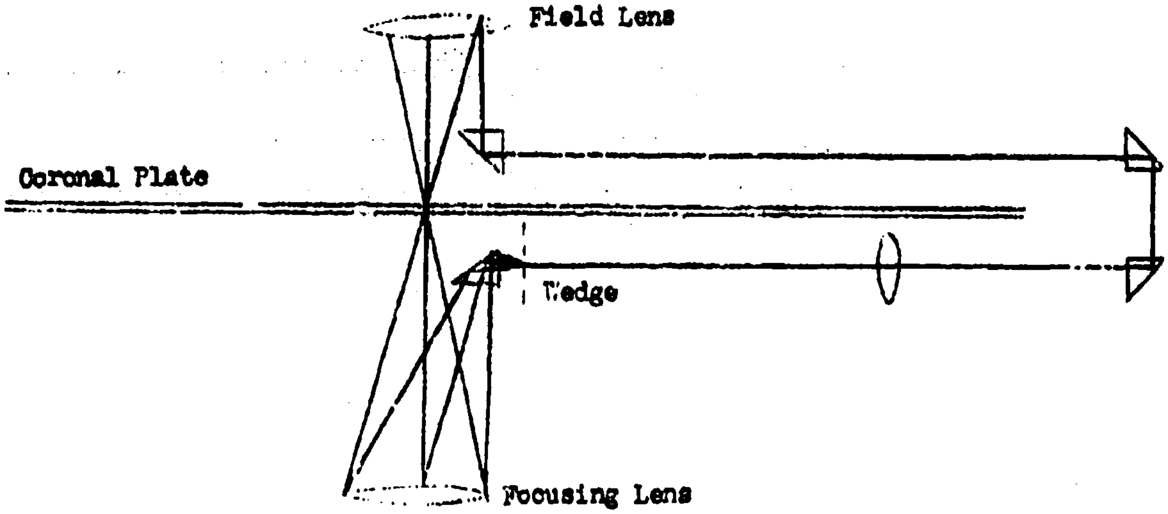


FIGURE 17

"B" Supply # 4

FIGURE 18

Optical System for use with Coronal Plates



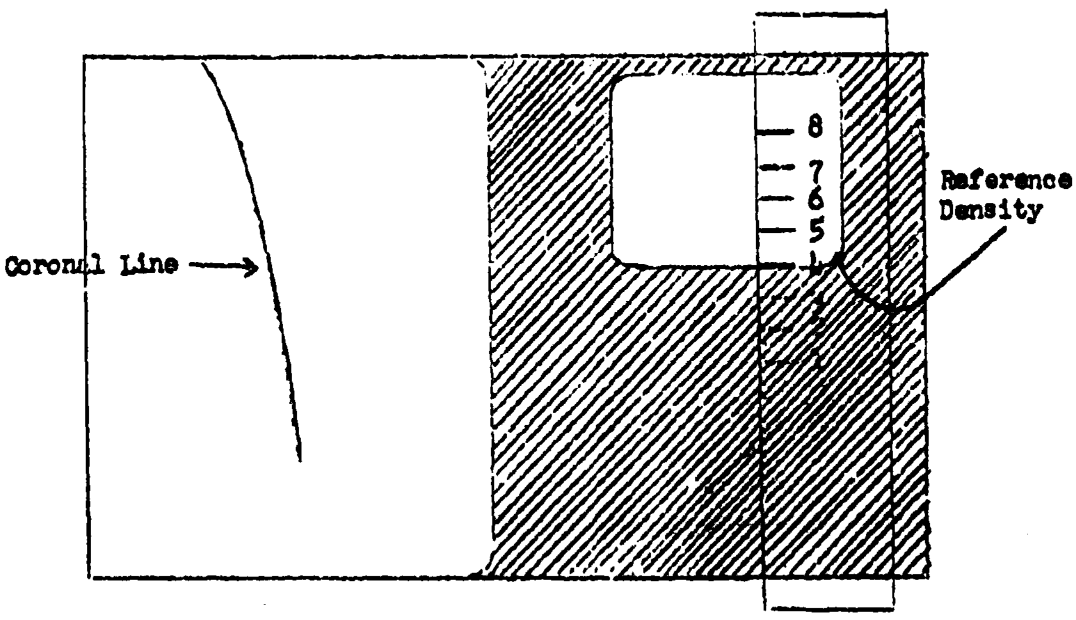
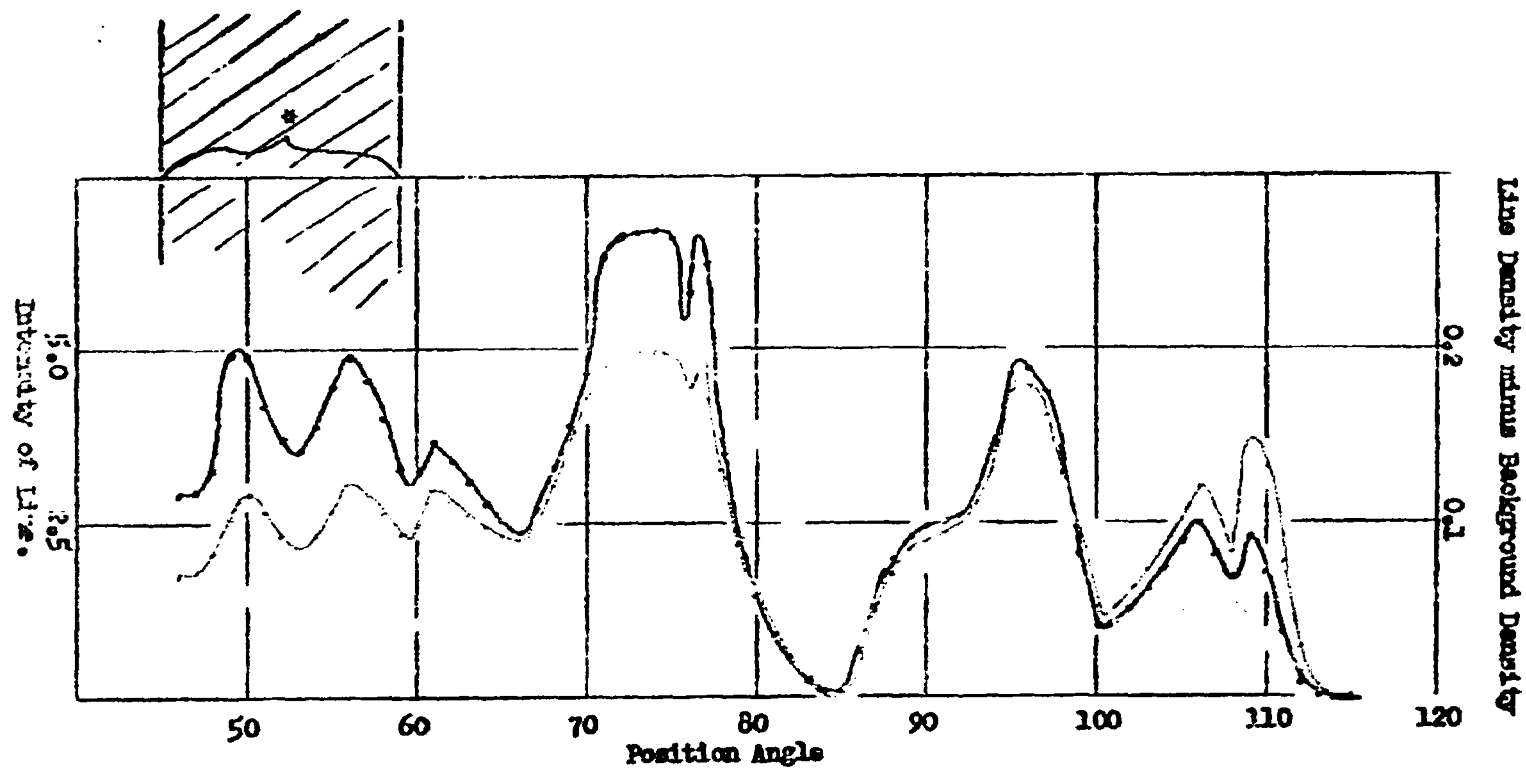


FIGURE 19

Viewing Screen When Using Attachment for Coronal Plates

FIGURE 20

Brightness of Green Coronal Line 16 Dec 1951 P-1418



——— Measured by the Contour Densitometer (relative line intensity.)
Measured Visually by W.O.Roberts in an arbitrary scale.
. . . Line Density minus Background Density.

* In this region the background was much more dense than on the rest of the plate. Contour Densitometer line densities minus background densities correspond to the visual readings more closely than the curve drawn, which is translated into the intensity scale.

ACKNOWLEDGEMENTS

As with other devices developed at the Observatory, a great deal of group analysis and discussion influenced the final product. Many people contributed practical suggestions that have gone unmentioned in the test. We gratefully acknowledge these. In particular, Dr. John W. Evans has played a large role in shaping our thoughts about this instrument.

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Donald S. Johnson

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High Altitude Observatory
Boulder, Colorado

29 January 1952

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Walter Orr Roberts
Walter Orr Roberts

26 February 1952